THE VASOMOTOR FACTOR IN THE CLINICAL MEASUREMENT OF THE BLOOD PRESSURE.[1]

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In this contribution specific reference will be made to blood pressure observed in arteriosclerosis. To me one of the most paradoxical manifestations of arteriosclerosis is the pronounced high blood pressure coupled with the local evidence of cardiac incompensation. The latter refers specifically to the enfeebled heart revealed by cardiac auscultation. In other words, the cardiac tones are weak, whereas the blood pressure is relatively high. In his studies in stethophonometry[2] the writer was better able to appreciate the foregoing fact than he would be were he guided by the conventional method of cardiac auscultation. The stethophonometer is a little piece of mechanism with coarse and fine adjustment attachable to the stethoscope containing a composition material which offers gradual increasing resistance to sound. The stethophonometer demonstrates that the intensity of the heart tones is no accurate gauge of heart strength. The instrument in question enables one to differentiate the muscular and valvular components of the heart sounds, and serves further to distinguish murmurs of valvular and muscular genesis.

Another important aid furnished by the instrument is in recognizing organic from inorganic cardiac murmurs and autochthonous from transmitted murmurs. Elsewhere[3] the writer has referred to inhibition of the heart as an aid in diagnosis. This manœuvre took into consideration the fact that the intensity of a cardiac murmur was dependent on the vigor of the heart. Loud murmurs often become weak or disappear in the course of febrile affections and in the moribund state owing to the slow and feeble action of the heart. The expedient in question seeks to slow the action of the heart, and in its execution we are constrained to rely on the efforts of the patient. This is not necessary if the stethophonometer is employed. By interposing increasing resistance to transmission inorganic and transmitted murmurs may be made to disappear to be replaced by tones. The stethophonometer has taught the writer that the unreserved reliance placed on the tonometer and other instruments for gauging blood pressure in arteriosclerosis is unwarranted by clinical evidence. It is usually taught that when the tonometric figure is low, with clinical evidence of arteriosclerosis, it is a sign of failing heart power. The tonometer and other like apparatus are constructed on the general principle that, after the blood supply to a part is inhibited by compression, the gradual removal of the latter will relieve the obstruction, and, when the point is attained at which the intra-arterial is greater than the extra-arterial or capillary pressure, it is indicated by a gauge which registers the blood pressure.

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[1] Read by invitation before the Oregon State Medical Association, Portland, Oregon, August 30, 1904.

[2] Abrams. Diseases of the Heart, 1900, p. 169; Medical News, July 8, 1699; New York Medical Journal, October 18, 1902.

[3] Philadelphia Medical Journal, September 29, 1900.

Now, in arteriosclerosis even the smallest bloodvessels (arterio-capillary fibrosis) are firm and unyielding, hence the compression of such vessels for gauging blood pressure conduces to erroneous results. Three factors make up the normal blood pressure, viz., force of the ventricle, frictional resistance of the capillaries, and arterial elasticity.

If the heart is weak, as is manifested by an enfeebled second aortic tone, increased blood pressure can never indicate a vigorous heart action, as is currently supposed. I am, therefore, constrained to conclude that in estimating the vigor of the myocardium blood pressure is of subsidiary value only and then when coupled with cardiac auscultation. There is unquestionably a vasomotor factor concerned in the maintenance of high blood pressure when cardiac enfeeblement coexists. I fully realize that I am running counter to orthodox teaching when I assume the contention that relatively high blood pressure is the necessary corollary of a weak heart. Compensation in cardiac anomalies is not necessarily confined to an increased capacity for work of the heart musculature, for there are many other compensatory factors, as, for instance, the augmentation of vascular tone in mitral stenosis and the diminution of the same tone in aortic regurgitation. We are in a position to estimate the degree of myocardial insufficiency, but the sufficiency of vasomotor and nerve influences in maintaining the circulation has heretofore baffled the efforts of clinical interpretation. Whereas, it is true that augmented peripheral resistance represented by increased function of the vasomotor nerves calls forth the latent energy of the heart, such increase in energy is fully compensated by the diminution in the number of heart beats. In general, increased blood pressure denotes a diminished and lowered blood pressure, an increased frequency of the pulse. One cannot gainsay that of the two conditions, increased blood pressure and increased energy of the heart, the former is preferable.

The blood supply to the heart occurs during diastole, and inasmuch as an increased pulse rate is at the expense of diastole, the nutrition of that organ must necessarily suffer. The nutrition of the heart is dependent on the pressure in the aorta, and when this sinks less blood is propelled into the coronary arteries. Such is the inconsistency of the average practitioner that, while he looks askance at high blood pressure and endeavors to subdue it, he does not hesitate to goad the heart by cardiotonic medication. Increased peripheral resistance of the bloodvessels serves as a prop to the enfeebled heart. We are inclined to forget that the elastic reaction of the arterial walls is an important factor in aiding the circulation of the blood, in fact, the arterial system is a subsidiary heart.

A rigid artery even in early arteriosclerosis is of no earthly benefit to its possessor; indeed, it is an incumbrance, yet that very artery may be made to yield its modicum of duty by augmented activity of the vasomotor system of nerves which puts it in a condition of moderate contraction. Thus the nervous system may compensate an impaired myocardium. That the bloodvessels are by no means a subordinate factor in furthering the circulation is evidenced by the recent observations of Hasebroek.[1] This writer tentatively proclaims a new theory based on the fact that there is a propulsive energy at the periphery independent of that in the heart, and that the periphery represents another second independent pumping apparatus, coupled with that of the heart. The periphery has not only its elastic contraction and expansion, but also its active diastole and systole in the arteries. This diastolic systolic activity is manifested in the capillaries as a sucking-in, an inspiration, as it were, while in the arteries it is more of a propulsive energy. Both these forces combine to create an independent and forcible stream into the veins which are passive and merely serve as a passive reservoir for the blood stream.

It is generally conceded that all of the factors that make up blood pressure the resistance offered by the bloodvessels is paramount. If the vessels are dilated, the pressure falls; if contracted, it will rise.

The nervous mechanism which presides over the tonus of the bloodvessels is the vasomotor apparatus, and while the latter I concede may be reflexly influenced by irritation from the bloodvessels themselves or from the end organs of sensory nerves in general, we are inclined to forget that the vasomotor apparatus may operate independently of such influences. Emotions and the state of the mind in general greatly influence the calibre of the bloodvessels through the vasomotor system of nerves. Take neurasthenics for a paradigm, and I have examined a large number of them at different periods under emotional influences, intense mental application, and when their brains were at rest, and in each instance my results varied. Emotional influences and intellectual application increased blood pressure, while mental rest reduced it. Again, increased cardiac pressure does not react equally on all the bloodvessels, and this is evidenced by the fact that the blood pressure in both radials is not always the same. Physical activity, the ingestion of food, menstruation, and other conditions also modify blood pressure. Another and more important factor influencing blood pressure is the heart volume, which is continually subject to reflex conditions. The writer has repeatedly demonstrated the occurrence of the *heart reflex* as a result of nasal and gastric irritation as well as by irritation of the skin over the precordial region. The writer's heart reflex has been repeatedly confirmed notably by Merklen and Heitz[1] and Heitler.[2]

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[1] Deutsche Archiv f. klin. Med., Berlin, Bd. lxxvii, Nos. 3 and 4.

The writer has recently demonstrated also a heart reflex of dilatation, aortic reflexes and myopathic and psychic heart reflexes,[3] facts which still further suggest variations in heart volume and changes in blood pressure. Without entering further into a discussion of these preliminary facts we may at once proceed to determine if possible how the clinical vasomotor factor may be excluded in estimating the blood pressure. In the following investigations the Riva-Rocci instrument was employed in gauging blood pressure. After the blood pressure was determined according to the customary method, the patient was instructed to inhale nitrite of amyl from a bottle, after which procedure the blood pressure was again estimated, and the difference noted. The arm-piece of the instrument need not be removed until the investigations are completed.

It is wise to instruct the patient not to practice forced breathing while inhaling the amyl nitrite, as observation has taught me that this physiologic act will reduce blood pressure and thus negative the clinical findings. Sufficient of the drug must be inhaled to induce the physiologic action, viz., slight duskiness of the face, fulness in the head, and relaxation of the bloodvessels. A few words noted elsewhere[4] are here apposite with reference to the physiologic action of the drug.

Amyl nitrite will intensify feeble cardiac murmurs, but ordinarily it is not serviceable in diagnosis, owing to the creation of cardiomuscular murmurs, which have no reality other than in the delirious state of the organ.

To bring out aneurysmal pulsations while the *x*-rays are traversing the chest, it is indispensable, although the aortic reflexes are more available in this regard.

During the inhalation of amyl nitrite in a certain percentage of persons the transverse diameter of the heart will become diminished. This drug is almost a specific in inhibiting the distress of angina pectoris, and if it reduces the cardiac area as the writer has demonstrated, the theory of Heberden, that angina pectoris is a cramp of the heart muscle, must be wrong. The theory of extreme tension of the ventricular walls in consequence of acute dilatation seems to be corroborated by the action of the drug upon the heart.

I have observed another phenomenon associated with the inhalation of amyl nitrite, and that is a limited patch of dulness which develops over the manubrium sterni.

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[1] La presse médicale, August 1, 1903.

[2] Wiener klin. Wochen., 1890; and Centralbl. f. d. ges. Therapie, 1893.

[3] American Medicine, January 3, 1903.

[4] Ibid., July 16, 1904.

This patch of dulness may involve the entire manubrium and extend to the right as well as to the left side. The dulness in question is almost never reproduced after an immediate second inhalation of the drug. The dulness is caused by circumscribed collapse of lung (the lung reflex of contraction). In some persons inhalation of the drug evokes dull areas in other chest regions, but the manubrium dulness is practically constant. The latter area of dulness may at once be dissipated by tapping the epigastrium, which provokes the counter lung reflex of dilatation. In the following table the blood pressure of ten average normal individuals is presented showing the influence on blood pressure after inhalation of amyl nitrite during the time that the face of the patient was flushed, the latter being in the sitting posture:

Case.	Age.	Blood pressure before and after inhalation of amyl nitrite.	
		Before.	After.
1	10	115 mm.	125 mm.
2	13	125 "	145 "
3	20	133 "	140 "
4	20	140 "	143 "
5	25	135 "	139 "
6	19	123 "	123 "
7	33	148 "	150 "
8	25	134 "	142 "
9	27	158 "	160 "
10	36	153 "	165 "

In the foregoing table one notes that the average effect of amyl nitrite inhalation in the normal individual is to cause a slight inincrease of blood pressure.

One may also observe in the examination of the normal individual that the primary effect of the inhalation is to slightly depress the blood pressure, but it rises at once. I am inclined to conclude that in the average healthy person the inhalation of amyl nitrite relaxes the arterial wall by elimination of the vasomotor influence, thus bringing into play the veritable cardiac pressure.

An examination of many arteriosclerotics after the foregoing procedure prompts me to classify them as follows:

1. Arteriosclerotics with high blood pressure and strong cardiac tones who show after inhalation of amyl nitrite a stabile or a slight rise of blood pressure, as is demonstrated by the selection of the following subjects:

Case.	Age.	Blood pressure before and after inhalation of amyl nitrite.	
		Before.	After.
1	62	157 mm.	163 mm.
2	68	210 "	210 "
3	68	160 "	165 "
4	60	168 "	168 "
5	64	174 "	176 "

2. Arteriosclerotics with high blood pressure and enfeebled cardiac tones, who show after the inhalation a decided decrease of blood pressure. In these as well as in the succeeding class the reduction in blood tension was no doubt influenced by the elimination of the tonus of the arteries, which was maintained by the vasomotor system of nerves, thus allowing the true endocardial pressure, which was enfeebled, to be brought into action.

Case.	Age.	Blood pressure before and after inhalation of amyl nitrite.	
		Before.	After.
1	74	218 mm.	190 mm.
2	59	240 "	195 "
3	62	200 "	175 "
4	71	210 "	180 "
5	60	290 "	240 "

3. A final class of patients with arteriosclerosis with relatively low blood pressure and enfeebled heart tones who demonstrate a still further reduction of blood pressure after inhalation of amyl nitrite, as the following table shows:

Case.	Age.	Blood pressure before and after inhalation of amyl nitrite.	
		Before.	After.
1	53	125 mm.	115 mm.
2	60	120 "	115 "
3	65	150 "	125 "
4	70	130 "	120 "
5	61	135 "	130 "

In a prognostic sense the patients in the last class belong to the hopeless category, insomuch as the vasomotor system of nerves is either exhausted or unable to properly usurp the functions of a failing heart.

Desirous of determining the influence of digitalis on some of the preceding cases, I have selected from the second class of arteriosclerotics Cases I. and V. and from the third class Cases II., IV., and V. A tablespoonful of a reliable infusion of digitalis was administered three times a day for five days, when it was presumed that the digitalis had brought about its physiological effects, and the following results were attained:

Class.	Case.	Blood pressure after using	
		Digitalis.	Amyl nitrite.
2	1	215 mm.	150 mm.
2	5	240 "	200 "
3	2	160 "	130 "
3	4	140 "	130 "
3	5	140 "	135 "

Digitalis is the sovereign heart tonic, and is correctly specified as the quinine of the heart. All heart tonics are divided into direct and indirect: the former acting by direct stimulation of the heart, the latter by improving the nutrition of the organ or by relieving vessel tension hastening the output of blood from the heart.

The digitalis substances in the therapeutic stadium have a dual action by slowing the pulse and augmenting the blood pressure. The latter is the product of two forces, viz., increased heart work and augmentation of the vessel tone.

The action on the heart of the digitalis substances is to increase the work of both ventricles, but in not a few instances increased work on the part of the left ventricle signifies an increased blood pressure which is very often an undesirable condition, as in nephritides and arteriosclerosis. It is usually taught that high blood pressure as in arteriosclerosis is a contraindication for the administration of digitalis, although Sahli[1] has demonstrated that in conditions of stasis with increased peripheral resistance digitalis possesses a paradoxical action, insomuch as it combats the stasis and reduces the blood pressure. Some of the theories established for the purpose of creating indications and contraindications for the administration of digitalis suggest the comment of the mathematician, who, having demonstrated a new mathematical theory, thanked God that it could not be of the slightest utility to any living soul. Many of the theories in question also remind me of the erudite German professor of economics who received a bed as a present. Until the small hours of the morning he busied himself with abstruse calculations to determine whether he was large enough for the bed or if the latter were large enough for him. Finally, he was struck with the happy idea of getting into the bed, and to his intense delight discovered that it was admirably suited to his proportions.

So it is with digitalis; this valuable cardiotonic is often relegated to oblivion owing to the numerous theories which indicate and contraindicate its employment.

No theory can guide the practitioner in the use of digitalis, and its tentative administration is always warranted, provided the physician begins with small doses and is prepared to recognize its untoward effects.

I have never permitted the high blood pressure nor the tortuous arteries in arteriosclerosis to thwart me in the use of digitalis, and my temerity, if it may be so specified, has rarely guided me into error. Very true, my conception of blood pressure in arteriosclerosis may be heterodoxical, and it is perhaps for this very reason that I have ignored the circumspection of the doctrinaire.

The cases cited in the table showing the effects on blood pressure after the use of digitalis may serve as a vehicle for my contention. In Class 2, Case I., the blood pressure before using digitalis was 218 mm., and after inhalation of amyl nitrite it was reduced to 190 mm. After the use of digitalis it was 215, but the inhalation of amyl nitrite reduced it to 150 mm. Now, the theory of action of the drug on the patient is practically as follows: The blood pressure was essentially the same after as before the use of digitalis, but while amyl nitrite before the use of digitalis reduced the blood pressure only 28 mm., after its use the pressure was reduced 65 mm. This indicated that the digitalis was unfavorable in its action, for, after the tonus of the bloodvessels was removed by amyl nitrite the greater reduction in blood pressure demonstrrated the cardiac force was further reduced after than before the use of digitalis. In other words, digitalis was goading a jaded heart, and the high blood pressure was illusory. This action is not uncommon in the administration of digitalis, owing to its vasoconstrictor influence, and when the latter action implicates the coronary bloodvessels the nutrition of the heart must suffer. In such instances, in determining the action of digitalis, we must often decide whether prolongation of the diastole can compensate for the defective nutrition.

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[1] Verhandl. d. XIX. Kongr. f. innere Med.

In the case last cited the action of digitalis was unfavorable, but when it was given in combinatiom with *diuretin*, which seems to antagonize the vasoconstrictor components of digitalis, the action of the latter drug was more favorable, the blood pressure falling only 15 mm. in lieu of 65 mm.

This combination of diuretin with digitalis in arteriosclerosis is more often advantageous than the combination of the latter drug with nitroglycerin. Very frequently the use of a brisk purgative in arteriosclerosis—*e. g.*, a combination of calomel and jalap for the purpose of unloading the bloodvessels—will be productive of more good than anything else, and will also further the action of digitalis and other cardiotonics. Whereas, the degree of passive hyperæmia of the lungs may be regarded as a gauge of the functional capacity of the right heart ventricle so, also, may the size of the liver be utilized as a guide of venous stasis, for the latter organ is practically a reservoir for the right ventricle. Even in the early stages of cardiac insufficiency the liver enlarges, whereas in the later stages the systolic liver pulse indicates that a tricuspid insufficiency has been added to dilatation of the right ventricle.

What I have called the cardiosplanchnic phenomenon serves a useful purpose in determining the grade of congestion in the splanchnic area. This phenomenon is based on the experimental investigations of Hill and Barnard,[1] who demonstrated that there is a tendency for the blood to accumulate in the splanchnic area, and that the great splanchnic veins are very susceptible to pressure, and that a large quantity of blood may be squeezed out of them by firm compressions of the belly with the hand. If a series of firm abdominal compressions with the hand are made in the average individual and the lower sternal region—*i. e.*, the part of the sternum contiguous to the heart is percussed—a pronounced dulness or even flatness will have been found to supersede the normal resonance.

The dulness in question is at once dissipated by a series of deep breaths. This is the cardiosplanchnic phenomenon, and is dependent on the fact that by abdominal compression blood is expressed from the splanchnic veins to the right heart. In some individuals the phenomenon is but feebly expressed, and its degree of expression is proportional to the grade of congestion of the splanchnic veins. If in arteriosclerosis, splanchnic congestion is pronounced digitalin or strophanthin alone or in combination are especially indicated. They are endowed with the property of constricting the splanchnic vessels alone, whereas digitoxin exerts its vasoconstrictor influence on all the bloodvessels. In the action of digitalin and strophanthin we possess a cogent means of relieving the burden of the heart by increasing the receptivity of the peripheral bloodvessels for the blood which has been expressed from the abdominal organs, and the same agents are almost specific in action in relieving splanchnic congestion, which is the underlying condition in splanchnic neurasthenia. For relieving splanchnic congestion the abdominal application of the sinusoidal current is paramount. A few words may be permitted with reference to the action of amyl nitrite. With this drug there is frequently an idiosyncrasy expressed; the subjects are either abnormally susceptible or refractory to its physiological action. In two instances following its inhalation the writer noted a veritable inhibition of the heart and absence of the pulse. The writer recalls a previous statement, viz., that the inhalation of amyl nitrite causes a reduction in the heart volume which is tantamount to a heart reflex, and in the two subjects just cited during the time the drug was inhaled with the *x*-rays traversing the chest the reduction in the heart volume was very much exaggerated above the normal.

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[1] Abrams. Splanchnic Neurasthenia, 1904, p. 171, and THE AMERICAN JOURNAL OF THE MEDICAL SCIENCES, January, 1904.

A pertinent example of autosuggestion is afforded in one instance from the inhalation of amyl nitrite.

The subject, who had taken chloroform for an operation a few months before, contended while inhaling amyl nitrite that I was giving him chloroform, and in a minute or two he passed into a condition of narcosis, during which time he proved insusceptible to the infliction of pain.

This example of autosuggestion is somewhat analogous to that occurring in the practice of a well-known chloroformist who had occasion to give ether to an hysterical girl who was about to have two small scalp tumors removed.

He found that the ether bottle was empty, and while waiting for a new supply to be brought he instructed the patient how to take deep breaths. After a few deep inspirations she cried, "I am going off," and became unconscious. Both tumors were painlessly removed in this state. It was subsequently learned that the girl had taken ether once before, and the association of ideas merely recalled the effects of ether.

The writer formulates the following conclusions:

1. That blood pressure is an expression of action of two chief factors: ventricular force and vasoconstriction.

2. The inhalation of amyl nitrite will dissipate the vasoconstrictor factor and bring into play the ventricular force, which is the real factor to be encouraged in a failing heart.

3. The vasoconstrictor factor may and does compensate ventricular inadequacy, for it is essential in most cardioarterial diseases for the blood pressure to be maintained to afford better nutrition for the heart and to promote arterial elasticity as a means of establishing the circulation of the blood.

4. The recognition of the ventricular and vasomotor factors in blood pressure serves as a clue in the correct administration of cardiotonics.

5. In the individual endowed with cardiac health the removal of the vasomotor factor causes an increase in blood pressure, whereas the converse condition causes the latter to fall, and the degree of reduction is proportional to the degree of cardiac enfeeblement.

6. The execution of the foregoing manœuvres in estimating heart vigor is by no means comparable to a correct method of cardiac auscultation, although the latter method does not indicate how much of the cardiac force may be attributed to increased peripheral resistance. Cardiac auscultation in conjunction with the sphygmomanometer and the inhalation of amyl nitrite constitute the ideal methods for eliciting the real condition of things.

7. In estimating blood pressure the sphygmomanometer only gauges the force of the left ventricle, and to determine the sufficiency of the right ventricle auscultation of the pulmonic sounds and a physical examination of the lungs are alone adequate.

8. There are certain individuals in whom one finds high blood pressure without cardiac weakness, and after inhalation of amyl nitrite the blood pressure remains the same. Such cases are associated with traces of albumin in the urine, which is of low specific gravity, and are practically instances of incipient chronic interstitial nephritis.

9. It is evident that persistent high blood pressure dependent on augmented tonus of the vasomotor centre is a cogent etiological factor in arteriosclerosis independent of any other cause, and is merely the reaction of arterial overwork.

10. Just as myocardial sufficiency is tested by counting the pulse, first in the erect and then in the recumbent posture, and noting that the less pronounced pulse retardation is in recumbency, the greater the degree of heart insufficiency, so may vasomotor sufficiency be determined. Normally, there is a postural variation in blood pressure. In the erect posture blood pressure rises owing to compensatory arteriole contraction, and this difference between recumbency and standing varies between 15 and 30 mm., according to my measurements with the Riva-Rocci instrument. In vasomotor insufficiency the postural variations are reversed, and this is especially true in neurasthenia, notably the angiopathic form. The bromides, carried to their physiological effects, will cause high blood pressure to fall, if dependent on augmented tonus of the vasomotor centre.